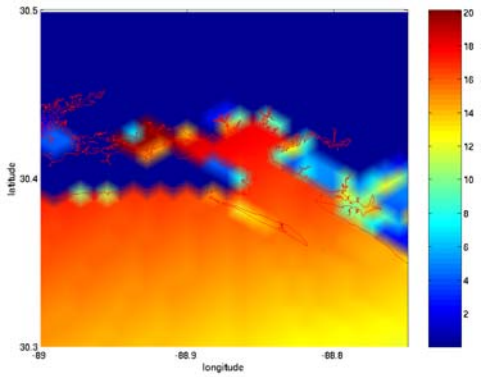
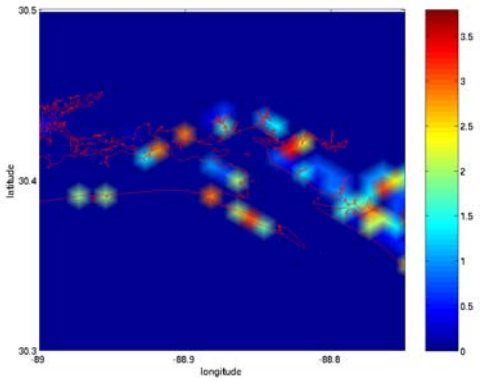
Technology Development and Transfer Office

John C. Stennis Space Center

Web-Based Hurricane Storm Surge and Flood Forecasting Using Optimized Interferometric SAR Bare-Earth DEMS



AD CIRC computed storm surge for Hurricane Camille using optimized bare-earth DEM for Eastern Biloxi Bay.



Absolute difference (in feet) for the Hurricane Camille storm surge simulation using optimized bare-earth DEM vsUSGS DEM

The process of creating a Digital Elevation Model (DEM) has just gotten easier with the development of a new automated software algorithm. Through a NASA Stennis Small Business Innovation Research (SBIR) Program contract, WorldWinds, Inc., of Picayune, MS, has taken an approach, which applies variational analysis to the derivation of bare-earth DEMS. The algorithm is used across various applications and has attracted the attention of several commercial companies as well as the emergency management agencies and US Navy.

The algorithm uses variational analysis to derive bare-earth Digital Elevation Models (DEMs) along the Mississippi Gulf Coast. The approach of applying interferometric SAR data is not wholly novel. Remote sensing experts have discussed its potential, but were frustrated by elevated objects, such as trees and buildings, and other noise masking the signal. Drawing upon past experiences and company expertise in Synthetic Aperture Radar (SAR) technology and weather prediction WorldWinds developed an approach to solve these problems. To implement this approach, WorldWinds drew on its relationship with Mississippi State University (MSU) at Stennis Space Center and used university expertise in applying variational analysis techniques to weather forecasting to develop an algorithm. This proved to be a daunting task as variational analysis takes an in-depth understanding of statistics, linear algebra and calculus, along with considerable scientific and programming skills

HOT Points

- **Incorporates "Variational Analysis" Techniques**
- **Upgrades present forecasting models**
- **Enhances product representations such as coastlines, inland areas and estuaries**
- **Other improvements include better representations as to height and depression from man-made elevation changes**
- **Reduces burden of manually editing datasets and can efficiently merge multiple datasets**

The variational analysis technique is very flexible. It can be generalized to include many complex measurements and constraints that simpler statistical techniques cannot incorporate. Datasets can be expanded beyond elevation to include remote sensing and optical techniques that represent specific digital signals. These signals can include vegetation indicators that can discern trees, grass, sand, etc., from satellite imagery, pixel colors that identify buildings or roads from optical imagery, and pixel brightness (proportional to backscatter strength) to identify ground cover types, such as smooth surfaces, rough surfaces, forests, and urban areas.

To prove this approach was feasible, WorldWinds ran a storm surge model using the DEM for Hurricane Camille (1969). This model, which is based on the Advanced Circulation model run by the Army Corps of Engineers and the Navy, is very complex and time-consuming, often taking a day or more to execute. WorldWinds used Interferometric Synthetic Aperture Radar (IFSAR) data and USGS-based DEM information and applied it to the elevation model of the Mississippi Gulf Coast. This combination coupled with variational analysis upgraded the bare-earth map in several ways. The most marked improvements were the representation of the coastline, immediate inland areas and estuaries. Such enhancements are critical towards hurricane preparedness and storm surge modeling.

Other improvements included better representation of height, especially at two meters and less, and depressions from man-made elevation changes (mostly highways), as well as the elimination of a majority of elevated objects.

The company used its time and money in the Phase II to further develop the concept into a fully automated algorithm for generating bare earth DEMs. WorldWinds used the same Intermap IFSAR data set and USGS data set from Phase I and worked to improve the variational analysis scheme. Other data used in its research included optical data sets from Digital Globe's QuickBird satellite to identify vegetation indices. WorldWinds also plans to use a NASA LIDAR data set for the study area. Phase II has proven that not only does the algorithm reduce the burden of manually editing datasets, but also that this technique can efficiently merge multiple datasets into an optimized bare-earth DEM estimation that minimizes the error characteristics of the datasets.

WHY THE TECHNOLOGY IS IMPORTANT

Variational analysis has been used successfully in other disciplines such as engineering, meteorology and the geosciences. It computes the most probable estimate from a variety of data sources. Almost any variable with a mathematical relationship can be used in the variational analysis technique, especially remote sensing measurements. It also allows multiple datasets, from a variety of sources, to be used in the software to upgrade the statistical relationships. This is why variational analysis is so robust and such an improvement over other statistical techniques.

The greatest benefit of the variational analysis technique is not necessarily the technique itself, but the vastly improved products it enables. One example is the refinement of elevation maps. Elevation data is an increasingly critical component of many operations requiring spatial information and the scale of elevation mapping projects and applications seems to grow bigger each year. Currently, local officials use storm surge and evacuation atlases to make decisions about the severity of risk to the local population due to a potential flooding event. These atlases are developed by the Army Corps of Engineers using US Geological Survey (USGS) elevation data. Although these maps are useful to officials, they leave much room for uncertainty. They are also difficult for non-technical people to understand.

WorldWinds is currently incorporating the new bare earth results in the Coupled Ocean Atmosphere Mesoscale Prediction System (COAMPS) developed by the Navy to create more accurate storm surge models. The company would replace the topographic datasets within COAMPS, coupled with ADCIRC, a storm surge model developed by the Army Corp of Engineers, to create new storm surge atlases. WorldWinds will compare actual datasets from previous storms, such as those of Hurricane Camille used in the Phase I, with those of the new forecast models.

SUCCESSES

Currently WorldWinds is partnering with Intermap Technologies of Englewood, Co., to incorporate its algorithm into Intermap products for the orthorectification of satellite and airborne imagery. Intermap is the commercial world leader in elevation mapping and plans to capitalize on its market and technology leadership by capturing complete national coverage of the United States, Japan and countries in Western Europe.

A spinoff partnership with the XM Satellite Radio Company, which is part of the WeatherWorks group, resulted from WorldWinds work with the COAMPS model. WorldWinds is selling output from the COAMPS weather model to be transmitted over the XM Satellite via a subscription service. With mariners as the primary audience for this information, WorldWinds and XM Radio will have a product kickoff Oct. 29 – Nov. 3, 2003, a t the Ft. Lauderdale, FL boat show.

Another partnership that has evolved in the technology's development is with Baron Services, of Huntsville, AL. Baron Services currently distributes WorldWinds' commercial weather product line and is interested in adding the storm surge and flood prediction forecasts into its current product offerings.

Thus far, WorldWinds has received more than $600k in NASA funding to continue development of the algorithm and other variational analysis-related technologies. WorldWinds has six employees to support this work, with one more position expected within a year.

TARGET MARKETS

Obvious markets that would benefit from the algorithm include the emergency preparedness industry, mapping and the remote sensing DEM industry. The market is wide open for the application of state-of-the-art remote sensing information to improve public safety. Federal and state agencies, such as Federal Emergency Management Agency, are evaluating IFSAR data as a potential solution for its Floodplain Map Reinvention Program, at significantly less cost and higher resolution than traditional means could achieve.

FUTURE OF THE TECHNOLOGY

Currently datasets have only been applied to the Mississippi Gulf Coast. While these have proven successful, access to more extensive information will increase the success rate of WorldWinds two commercial products: 1) variational analysis software that can produce optimized DEM maps for any region along the US coast; and 2) hurricane flood atlases for any coastal area.

These atlases will include higher-resolution storm surge simulations, rainfall effects, flash flood mapping, overlaid roads and detailed coastline information.

With theses new and improved atlases available on-line through the interactive web-based system, WorldWinds expects users to be able to turn layers on and off, such as road networks and landcover, making the system easy to use while still providing the most technologically advanced information available.

WorldWinds will continue to research applications of variational analysis through its relationship with the NASA Earth Science Enterprise. Weather and climate change are one of the 12 focus areas and WorldWinds is one of the featured companies.

Additionally, WorldWinds will continue refinement and validation of the software, especially in areas where the lack of ground truth hampers development and validation efforts.

WHY SBIR?

"The SBIR program was a great avenue for WorldWinds to pursue federal funding to drive this technology. Development of an automated DTM algorithm is market driven by users wanting a powerful, easy-to-use tool to orthorectify their imagery. Much of the commercial data sold today is bought by the federal government, specifically the DoD," said Elizabeth Valenti, owner of WorldWinds.

"If the commercial sector can provide a cost-effective means to orthorectify these data sets, everyone will win! A company as small as WorldWinds has a very limited R&D budget, so this SBIR funding has allowed us to develop new and exciting technology that would not otherwise have been possible," she said.

SBIR is a highly competitive multi-phase program that provides small U.S. businesses with federal funds reserved for conducting serious research and development. Phase I is the start-up segment with awards up to $70,000; if chosen, Phase II awardees are granted up to $600,000 to conduct research and development for two years. The SBIR Program at Stennis Space Center is managed through the Technology Development and Transfer Office. For more information regarding the NASA Small Business Innovation Research Program contact the Technology Development and Transfer Office at Stennis Space Center at (228) 688-1929 or visit the website at http://technology.ssc.nasa.gov.

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